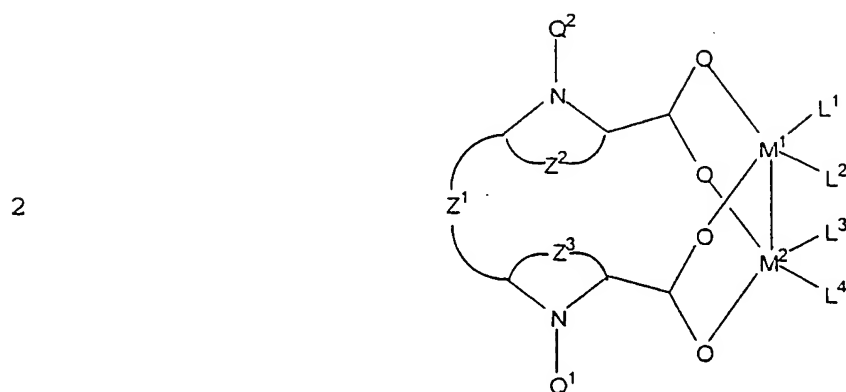


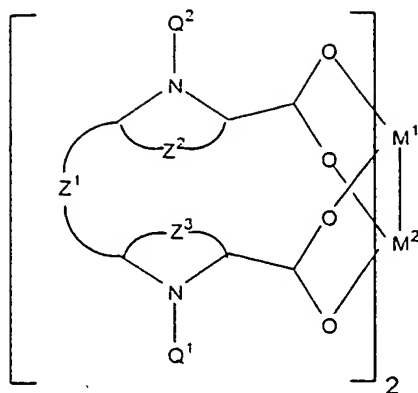
WHAT IS CLAIMED IS:

- 1                    1. A compound having the formula:



3    wherein  $M^1$  and  $M^2$  are the same or different and are  
 4    transition metal atoms or ions;  $Z^2$  and  $Z^3$ , independently,  
 5    are the atoms necessary to complete a 3-12 membered  
 6    heterocyclic ring;  $Z^1$  is an alkylene or arylene group;  $Q^1$   
 7    and  $Q^2$  are the same or different and are electron  
 8    withdrawing groups;  $L^1$  and  $L^3$ , taken together, represent  
 9     $-O-CR^{13}-O-$ ;  $L^2$  and  $L^4$ , taken together, represent  $-O-CR^{14}-O-$ ;  
 10    and  $R^{13}$  and  $R^{14}$  are the same or different and are selected  
 11    from the group consisting of alkyl groups and aryl groups  
 12    or  $R^{13}$  and  $R^{14}$  represent alkylene or arylene groups that  
 13    are directly or indirectly bonded to one another.

- 1                    2. A compound according to claim 1, having  
 2    the formula:



3  
1                    3. A compound according to claim 1, wherein M¹  
2 and M² are independently selected from Rh, Ru, Mo, Pd, and  
3 Re.

1                    4. A compound according to claim 1, wherein  
2 each of M¹ and M² is Rh.

1                    5. A compound according to claim 1, wherein Q¹  
2 is selected from the group of moieties having the  
3 formulae -C(O)R¹, -SO₂R¹, and -P(O)R¹R¹'; wherein Q² is  
4 selected from the group of moieties having the formulae  
5 -C(O)R², -SO₂R², and -P(O)R²R²'; and wherein each of R¹, R¹',  
6 R², and R²' is independently selected from an alkyl group,  
7 an aryl group, and an alkoxy group.

1                    6. A compound according to claim 5, wherein Q¹  
2 has the formula -SO₂R¹; Q² has the formula -SO₂R²; and R¹  
3 and R² are the same or different and are alkyl or aryl  
4 groups.

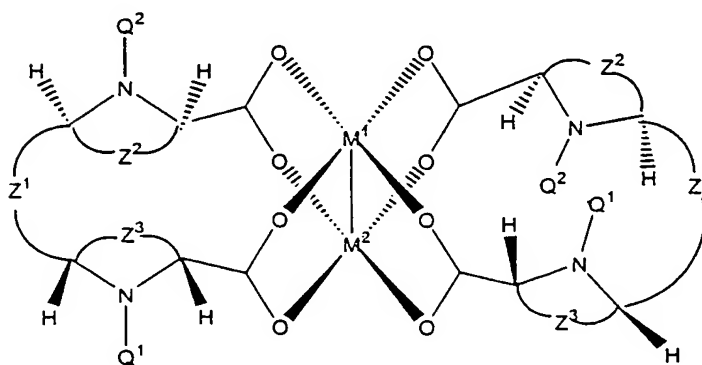
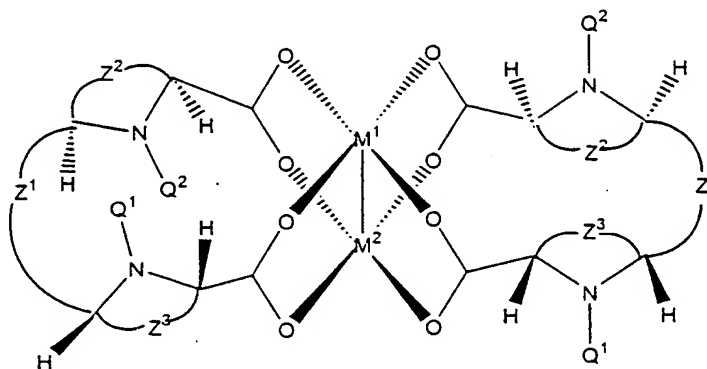
1                    7. A compound according to claim 6, wherein  
2 each of R¹ and R² is independently selected from the group

3 consisting of 4-(t-butyl)phenyl, 2,4,6-trimethylphenyl,  
4 and 2,4,6-triisopropylphenyl.

1 8. A compound according to claim 1, wherein  $Z^2$   
2 and  $Z^3$  each have the formula  $-\text{CH}_2\text{CH}_2-$ .

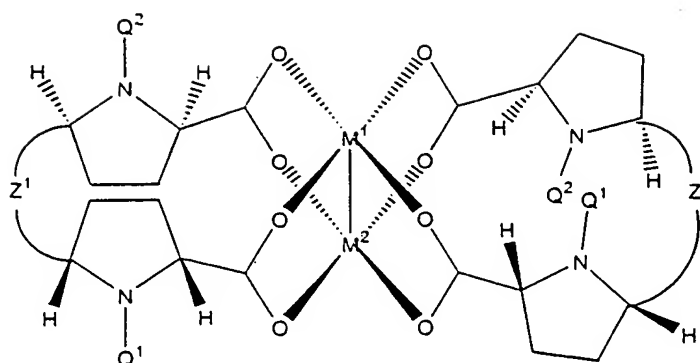
1 9. A compound according to claim 1, wherein  $Z^1$   
2 is 1,3-phenylene.

1 10. A compound according to claim 1 having one  
2 of the following formulae:

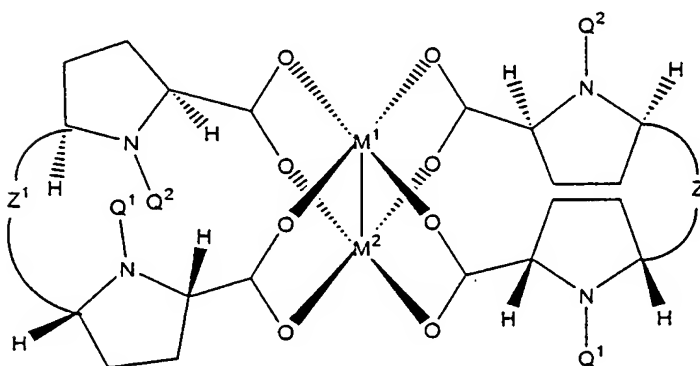


1 11. A compound according to claim 1 having one  
2 of the following formulae:

3

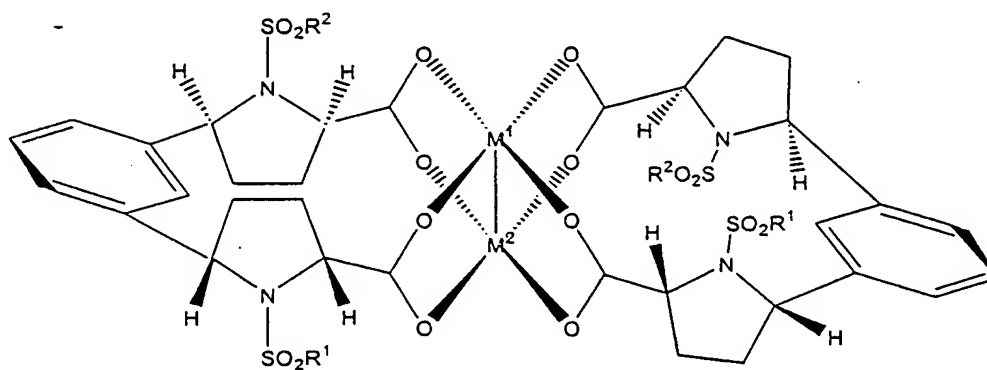


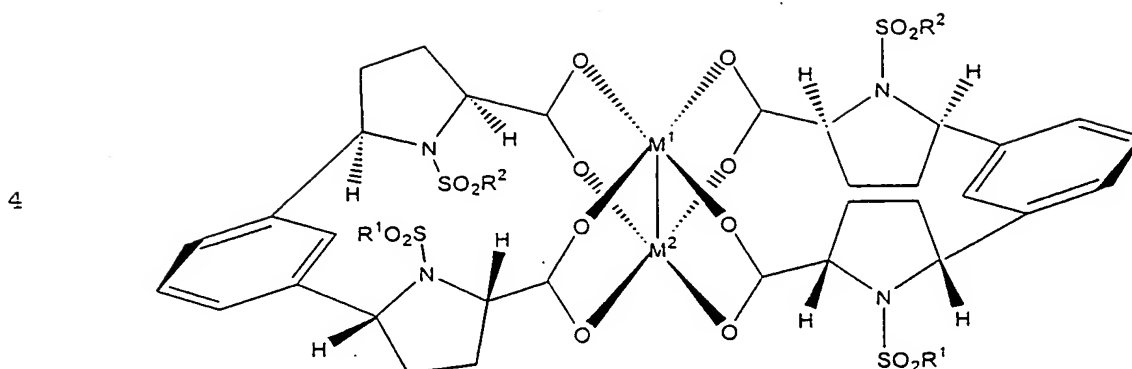
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1 12. A compound according to claim 1 having one  
2 of the following formulae:

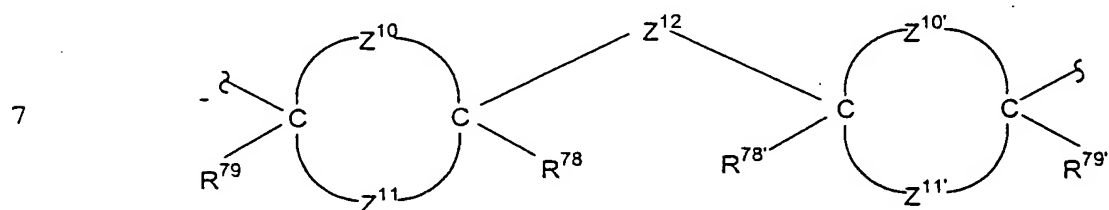
3





5 wherein  $R^1$  and  $R^2$  are the same or different and are alkyl  
6 or aryl groups.

1 13. A compound comprising:  
2 a first metal atom and a second metal atom  
3 bonded to one another along an axis, and  
4 two carboxylate ligands wherein each of said  
5 two carboxylate ligands comprises two carboxylate groups  
6 bonded to each other via a moiety having the formula:



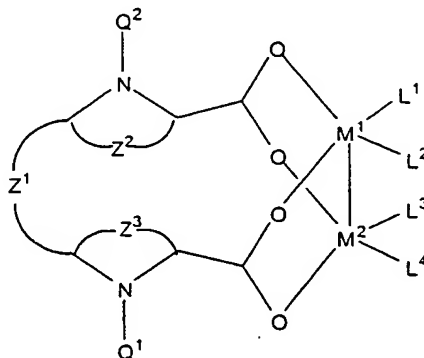
8 wherein  $Z^{10}$  and  $Z^{11}$ , together with the atoms to which they  
9 are bonded form a 3-12 membered ring; wherein  $Z^{10'}$  and  $Z^{11'}$ ,  
10 together with the atoms to which they are bonded form a  
11 3-12 membered ring; wherein  $R^{78}$ ,  $R^{78'}$ ,  $R^{79}$ , and  $R^{79'}$  are  
12 independently selected from the group consisting of H, an  
13 alkyl group, and an aryl group; wherein  $Z^{12}$  is an alkylene  
14 or arylene group; wherein each of said two carboxylate  
15 groups comprises a first carboxylate oxygen atom (" $O^1$ "), a  
16 second carboxylate oxygen atom (" $O^2$ "), and a carbon (" $C$ ")

17 to which said  $O^1$  and said  $O^2$  are bonded thereby forming  
 18 two  $O^1-C-O^2$  moieties, each  $O^1-C-O^2$  moiety defining a plane  
 19 which is substantially parallel to said axis; wherein  
 20 said  $O^1$  of each of said two carboxylate groups of each of  
 21 said two carboxylate ligands is bonded to said first  
 22 metal atom; wherein said  $O^2$  of each of said two  
 23 carboxylate groups of each of said two carboxylate  
 24 ligands is bonded to said second metal atom; wherein each  
 25 of said two carboxylate ligands further comprises at  
 26 least two chiral centers; and wherein said compound has  $D_2$   
 27 symmetry.

1 14. A compound according to claim 13, wherein  
 2 none of  $Z^{10}$ ,  $Z^{10'}$ ,  $Z^{11}$ , and  $Z^{11'}$  represents a direct bond  
 3 between the carbon atoms to which they are bonded.

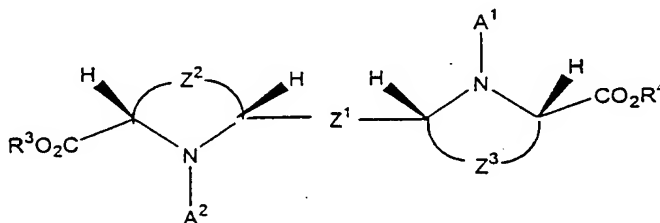
1 15. A compound according to claim 14, wherein  
 2 at least one of  $Z^{10}$  and  $Z^{10'}$  has the formula  $-NQ-$ , at least  
 3 one of  $Z^{11}$  and  $Z^{11'}$  is an arylene or alkylene group, and Q  
 4 is an electron withdrawing group.

1 16. A method for making a compound having the  
 2 formula:

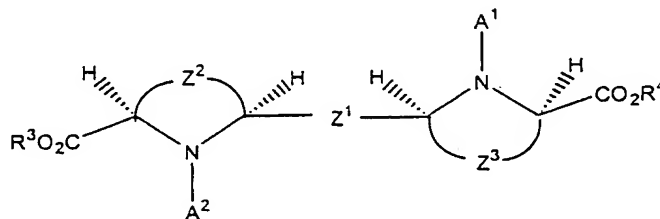


4 wherein  $M^1$  and  $M^2$  are the same or different and are  
 5 transition metal atoms or ions;  $Z^2$  and  $Z^3$ , independently,  
 6 are the atoms necessary to complete a 3-12 membered  
 7 heterocyclic ring;  $Z^1$  is an alkylene or arylene group; and  
 8  $Q^1$  and  $Q^2$  are the same or different and are electron  
 9 withdrawing groups;  $L^1$  and  $L^3$ , taken together, represent  
 10  $-O-CHR^{13}-O-$ ;  $L^2$  and  $L^4$ , taken together, represent  
 11  $-O-CHR^{14}-O-$ ; and  $R^{13}$  and  $R^{14}$  are the same or different and  
 12 are selected from the group consisting of alkyl groups  
 13 and aryl groups or  $R^{13}$  and  $R^{14}$  represent alkylene or  
 14 arylene groups that are directly or indirectly bonded to  
 15 one another, said method comprising:

16 providing a ligand having the formula:



18 or



20 or a mixture thereof, wherein each of  $A^1$  and  $A^2$  is  
 21 independently selected from the group consisting of a  
 22 hydrogen atom and an electron withdrawing group and each  
 23 of  $R^3$  and  $R^4$  is independently selected from the group  
 24 consisting of H, alkyl, and aryl; and

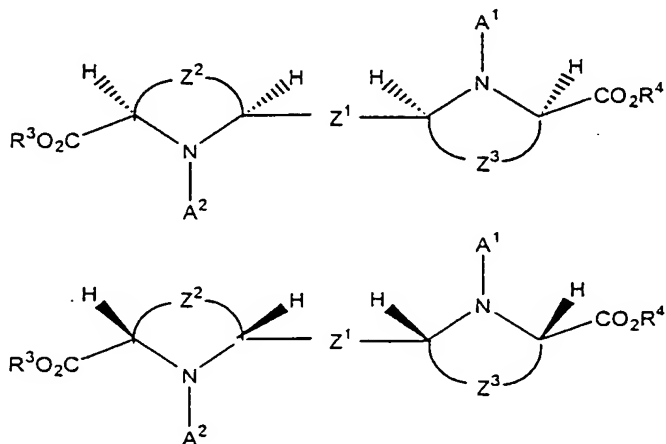
25 converting the ligand with a bis-metal salt  
 26 under conditions effective to produce the compound.

1            17. A method according to claim 16, wherein  $Z^2$   
 2 and  $Z^3$  each have the formula  $-\text{CH}_2\text{CH}_2-$ ; each of  $M^1$  and  $M^2$  is  
 3 Rh;  $Z^1$  is 1,3-phenylene;  $Q^1$  is selected from the group of  
 4 moieties having the formulae  $-\text{C}(\text{O})\text{R}^1$ ,  $-\text{SO}_2\text{R}^1$ , and  
 5  $-\text{P}(\text{O})\text{R}^1\text{R}^{1'}$ ;  $Q^2$  is selected from the group of moieties  
 6 having the formulae  $-\text{C}(\text{O})\text{R}^2$ ,  $-\text{SO}_2\text{R}^2$ , and  $-\text{P}(\text{O})\text{R}^2\text{R}^{2'}$ ; and  
 7 each of  $\text{R}^1$ ,  $\text{R}^{1'}$ ,  $\text{R}^2$ , and  $\text{R}^{2'}$  is an alkyl group, an aryl  
 8 group, or an alkoxy group.

1            18. A method according to claim 16, wherein  
 2 the bis-metal salt has the formula  $\text{M}^1\text{M}^2(\text{OOR}^5)_4$ , wherein  $\text{R}^5$   
 3 is an alkyl group or an aryl group.

1            19. A method according to claim 16, wherein  
 2 each of  $M^1$  and  $M^2$  is Rh and the bis-metal salt is  
 3  $\text{Rh}_2(\text{OOCH}_3)_4$ .

1            20. A compound having the one of the following  
 2 formulae:

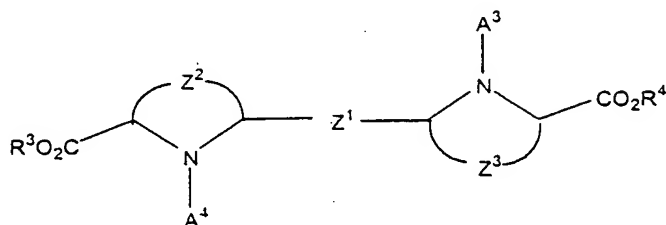


5 wherein  $Z^2$  and  $Z^3$ , independently, are the atoms necessary  
 6 to complete a 3-12 membered heterocyclic ring;  $Z^1$  is an  
 7 alkylene or arylene group;  $A^1$  and  $A^2$  are independently  
 8 selected from the group consisting of a hydrogen atom and



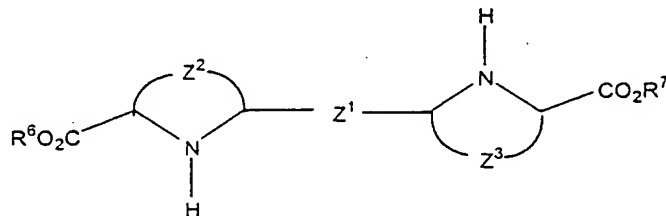
9 an electron withdrawing group; and each each of  $R^3$  and  $R^4$   
 10 is independently selected from the group consisting of H,  
 11 alkyl, and aryl.

1 21. A method for preparing an N-substituted  
 2 compound having the formula:



4 wherein  $Z^2$  and  $Z^3$ , independently, are the atoms necessary  
 5 to complete a 3-12 membered heterocyclic ring;  $Z^1$  is an  
 6 alkylene or arylene group;  $A^3$  and  $A^4$  are the same or  
 7 different and are electron withdrawing groups having the  
 8 formulae  $-C(O)R^2$ ,  $-SO_2R^2$ , or  $-P(O)R^2R^{2'}$ ; each of  $R^1$ ,  $R^{1'}$ ,  $R^2$ ,  
 9 and  $R^{2'}$  is an alkyl group, an aryl group, or an alkoxy  
 10 group; and each of  $R^3$  and  $R^4$  is independently selected  
 11 from the group consisting of H, alkyl, and aryl, said  
 12 method comprising:

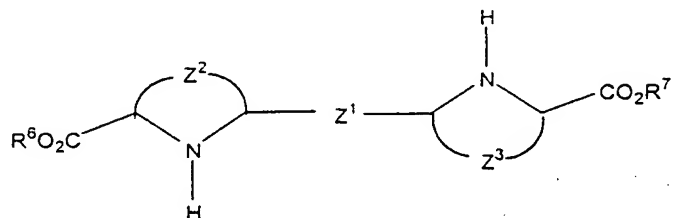
13 providing an N-unsubstituted compound having  
 14 the formula:



16 wherein  $R^6$  and  $R^7$  is independently selected from an alkyl  
 17 group or an aryl group; and

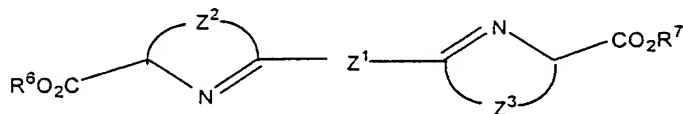
18 converting the N-unsubstituted compound to the  
19 N-substituted compound with an acylating agent, a  
20 sulfonylating agent, or a phosphonylating agent.

1 22. A method for preparing an N-unsubstituted  
2 compound having the formula:



4 wherein Z² and Z³, independently, are the atoms necessary  
5 to complete a 3-12 membered heterocyclic ring; Z¹ is an  
6 alkylene or arylene group; and R⁶ and R⁷ is independently  
7 selected from an alkyl group or an aryl group, said  
8 method comprising:

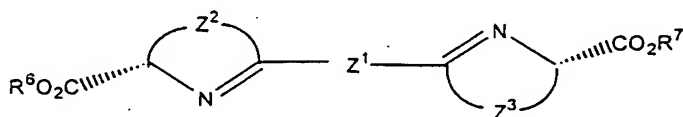
9 providing an unsaturated heterocyclic compound  
10 having the formula:

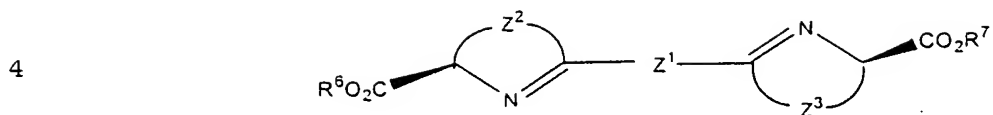


13 and

14 converting the unsaturated heterocyclic  
15 compound to the N-unsubstituted compound using  
16 hydrogenation.

1 23. A compound having one of the following  
2 formulae:

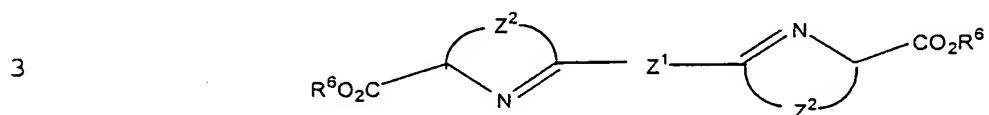




5 wherein Z² and Z³, independently, are the atoms necessary  
6 to complete a 3-12 membered heterocyclic ring; Z¹ is an  
7 alkylene or arylene group; and R⁶ and R⁷ is independently  
8 selected from an alkyl group or an aryl group.

1 24. A compound according to claim 23, wherein  
2 Z¹ is a 1,3-phenylene group.

1 25. A method for preparing an unsaturated  
2 heterocyclic compound having the formula:



4 wherein Z² represents the atoms necessary to complete a 3-  
5 12 membered heterocyclic ring; Z¹ is an alkylene or  
6 arylene group; and R⁶ is selected from an alkyl group or  
7 an aryl group, said method comprising:

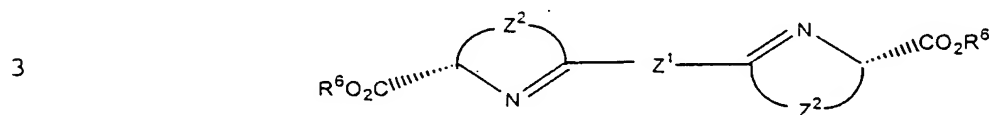
8 providing a cyclic ketone having the formula:



10 wherein R⁸ is an amine-protecting group; and  
11 converting the cyclic ketone to the N-  
12 unsaturated heterocyclic compound with a bis-lithium  
13 compound having the formula Z¹Li₂.

1                   26. A method according to claim 25, wherein  
2 the bis-lithium compound is 1,3-dilithiobenzene.

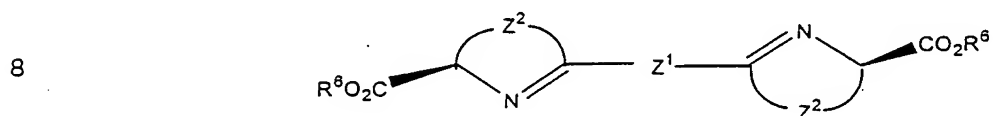
1                   27. A method according to claim 25, wherein  
2 the N-unsaturated heterocyclic compound has the formula:



4 and the cyclic ketone has the formula:



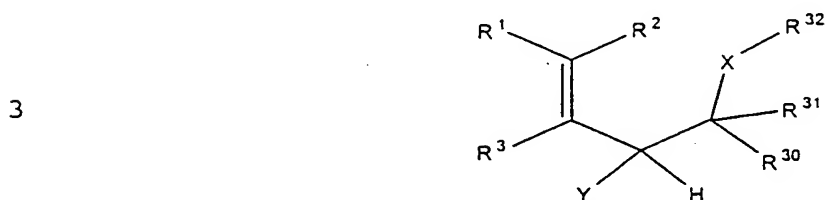
6 or wherein the N-unsaturated heterocyclic compound has  
7 the formula:



9 and the cyclic ketone has the formula:



1                   28. A method of producing a compound having  
2 the formula:



21



23

25



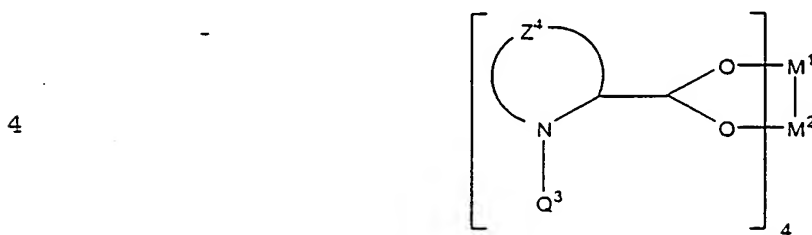
27

28 wherein  $X'$  is  $CH_2$ , O, or  $NR^{11'}$  and  $R^{11'}$  is an alkyl group,  
 29 an aryl group, an acyl group, an alkoxycarbonyl group, or  
 30 a silyl group, provided that when  $X$  is O or  $CH_2$ , when  $R^1$   
 31 and  $R^3$ , together with the atoms to which they are bonded,  
 32 form a 5-12 membered ring, and when  $R^{31}$  and  $R^{32}$ , together  
 33 with the atoms to which they are bonded, form a 5-12  
 34 membered ring, said converting is carried out  
 35 substantially in the absence of oxygen.

1                    29. A method according to claim 28, wherein  
 2 the bis-transition metal catalyst is a dirhodium or  
 3 diruthenium catalyst.

1                    30. A method according to claim 29, wherein  
 2 the dirhodium or diruthenium catalyst is a dirhodium or  
 3 diruthenium tetracarboxylate catalyst.

1                    31. A method according to claim 30, wherein  
 2 the dirhodium or diruthenium tetracarboxylate catalyst  
 3 has the formula:



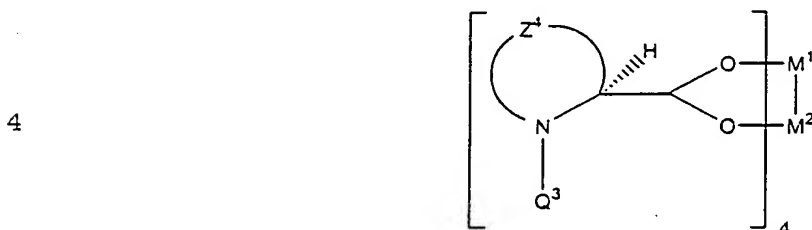
5 wherein each of  $M^1$  and  $M^2$  is Rh or Ru;  $Z^4$  represents the  
 6 atoms necessary to complete a 3-12 membered heterocyclic  
 7 ring; and  $Q^3$  is an electron withdrawing group.

1                    32. A method according to claim 31, wherein  $Z^4$   
 2 has the formula  $-CH_2CH_2CH_2-$ .

1           33. A method according to claim 31, wherein  $Q^3$   
 2 is selected from the group of moieties having the  
 3 formulae  $-C(O)R^9$ ,  $-SO_2R^9$ , and  $-P(O)R^9R^{9'}$  and wherein each of  
 4  $R^9$  and  $R^{9'}$  is independently selected from an alkyl group,  
 5 an aryl group, and an alkoxy group.

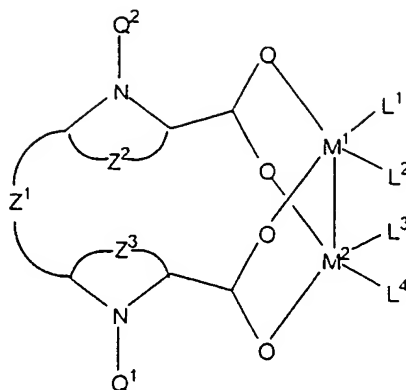
1           34. A method according to claim 33, wherein  $Q^3$   
 2 has the formula  $-SO_2R^9$  and wherein  $R^9$  is an alkyl or aryl  
 3 group.

1           35. A method according to claim 31, wherein  
 2 the dirhodium or diruthenium tetracarboxylate catalyst  
 3 has the formula:



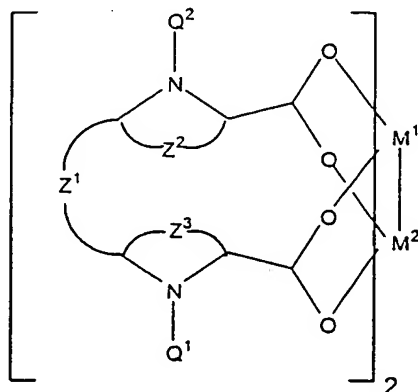
1           36. A method according to claim 35, wherein  
 2 the dirhodium or diruthenium tetracarboxylate catalyst  
 3 has  $D_2$  symmetry.

1           37. A method according to claim 30, wherein  
 2 the dirhodium or diruthenium tetracarboxylate catalyst  
 3 has the formula:



wherein each of  $M^1$  and  $M^2$  is Rh or Ru;  $Z^2$  and  $Z^3$ , independently, are the atoms necessary to complete a 3-12 membered heterocyclic ring;  $Z^1$  is an alkylene or arylene group;  $Q^1$  and  $Q^2$  are the same or different and are electron withdrawing groups;  $L^1$  and  $L^3$ , taken together, represent  $-O-CR^{13}-O-$ ;  $L^2$  and  $L^4$ , taken together, represent  $-O-CR^{14}-O-$ ; and  $R^{13}$  and  $R^{14}$  are the same or different and are selected from the group consisting of alkyl groups and aryl groups or  $R^{13}$  and  $R^{14}$  represent alkylene or arylene groups that are directly or indirectly bonded to one another.

38. A method according to claim 37, wherein the dirhodium or diruthenium tertracarboxylate catalyst has the formula:





1                   39. A method according to claim 37, wherein  
2 each of  $M^1$  and  $M^2$  is Rh.

1                   40. A method according to claim 37, wherein  $Q^1$   
2 is selected from the group of moieties having the  
3 formulae  $-C(O)R^1$ ,  $-SO_2R^1$ , and  $-P(O)R^1R^{1'}$ ; wherein  $Q^2$  is  
4 selected from the group of moieties having the formulae  
5  $-C(O)R^2$ ,  $-SO_2R^2$ , and  $-P(O)R^2R^{2'}$ ; and wherein each of  $R^1$ ,  $R^{1'}$ ,  
6  $R^2$ , and  $R^{2'}$  is independently selected from an alkyl group,  
7 an aryl group, and an alkoxy group.

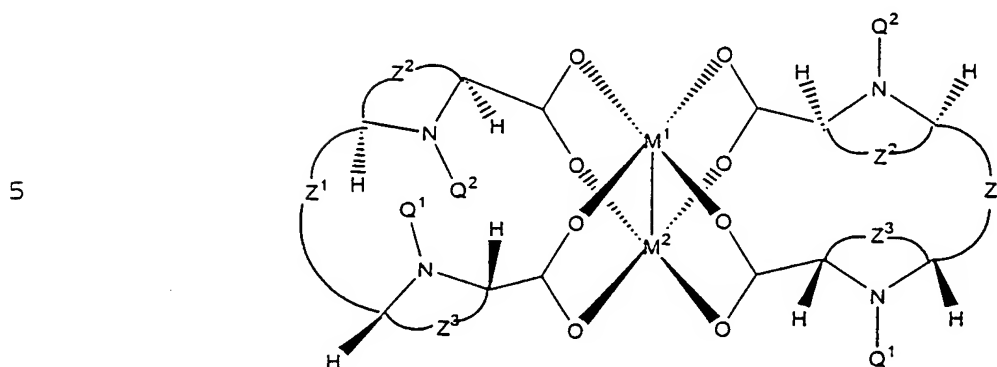
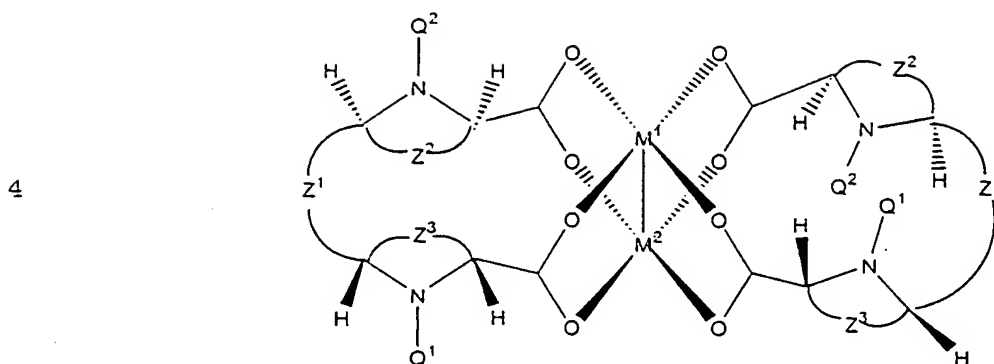
1                   41. A method according to claim 37, wherein  $Q^1$   
2 has the formula  $-SO_2R^1$ ;  $Q^2$  has the formula  $-SO_2R^2$ ; and  $R^1$   
3 and  $R^2$  are the same or different and are alkyl or aryl  
4 groups.

1                   42. A method according to claim 41, wherein  
2 each of  $R^1$  and  $R^2$  is independently selected from the group  
3 consisting of 4-(t-butyl)phenyl, 2,4,6-trimethylphenyl,  
4 and 2,4,6-triisopropylphenyl.

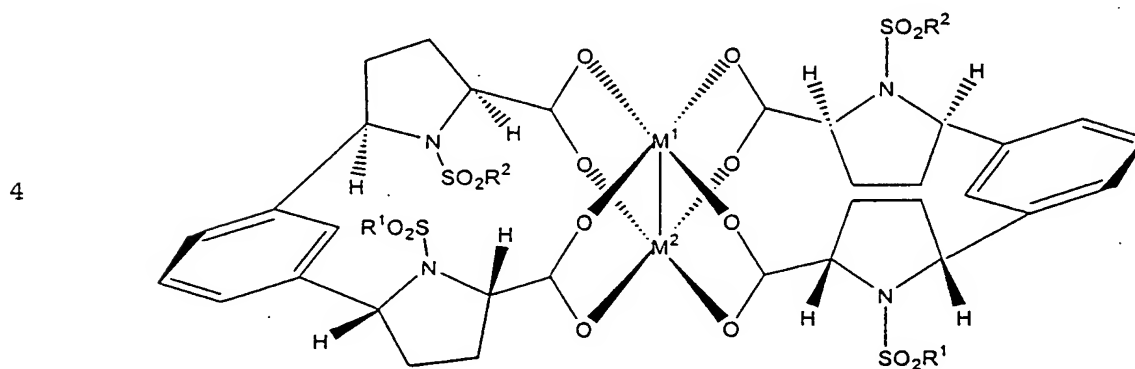
1                   43. A method according to claim 37, wherein  $Z^2$   
2 and  $Z^3$  each have the formula  $-CH_2CH_2-$ .

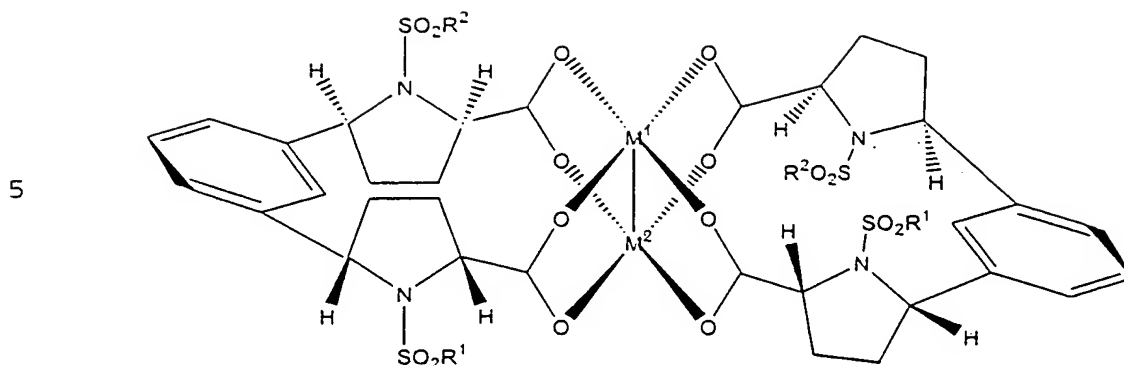
1                   44. A method according to claim 37, wherein  $Z^1$   
2 is 1,3-phenylene.

1                   45. A method according to claim 37, wherein  
2 the dirhodium or diruthenium tetracarboxylate catalyst  
3 has one of the following formulae:



1                    46. A method according to claim 37, wherein  
 2     the dirhodium or diruthenium tetracarboxylate catalyst  
 3     has one of the following formulae:

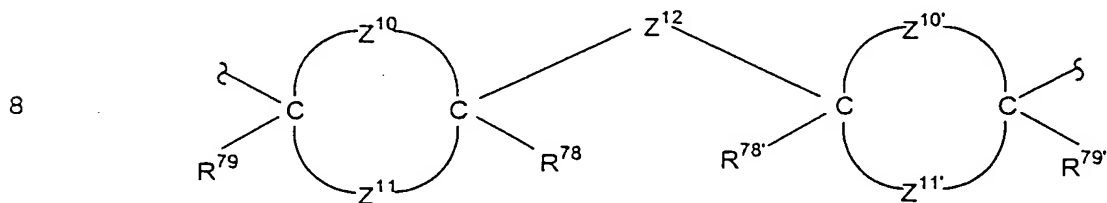




6 wherein  $R^1$  and  $R^2$  are the same or different and are alkyl  
7 or aryl groups.

1 47. A method according to claim 29, wherein  
2 the dirhodium or diruthenium catalyst is a chiral  
3 dirhodium or diruthenium catalyst.

1 48. A method according to claim 47, wherein  
2 the chiral dirhodium or diruthenium catalyst comprises:  
3 a first metal atom and a second metal atom  
4 bonded to one another along an axis and  
5 two carboxylate ligands wherein each of said  
6 two carboxylate ligands comprises two carboxylate groups  
7 bonded to each other via a moiety having the formula:



9 wherein  $Z^{10}$  and  $Z^{11}$ , together with the atoms to which they  
10 are bonded form a 3-12 membered ring; wherein  $Z^{10'}$  and  $Z^{11'}$ ,  
11 together with the atoms to which they are bonded form a

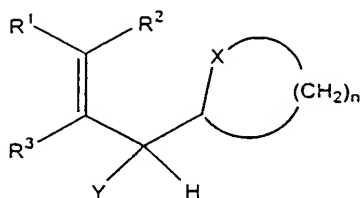
12 3-12 membered ring; wherein  $R^{78}$ ,  $R^{78'}$ ,  $R^{79}$ , and  $R^{79'}$  are  
13 independently selected from the group consisting of H, an  
14 alkyl group, and an aryl group; wherein  $Z^{12}$  is an alkylene  
15 or arylene group; wherein each of said two carboxylate  
16 groups comprises a first carboxylate oxygen atom (" $O^1$ "), a  
17 second carboxylate oxygen atom (" $O^2$ "), and a carbon (" $C$ ")  
18 to which said  $O^1$  and said  $O^2$  are bonded thereby forming  
19 two  $O^1-C-O^2$  moieties, each  $O^1-C-O^2$  moiety defining a plane  
20 which is substantially parallel to said axis; wherein  
21 said  $O^1$  of each of said two carboxylate groups of each of  
22 said two carboxylate ligands is bonded to said first  
23 metal atom; wherein said  $O^2$  of each of said two  
24 carboxylate groups of each of said two carboxylate  
25 ligands is bonded to said second metal atom; wherein each  
26 of said two carboxylate ligands further comprises at  
27 least two chiral centers; and wherein said compound has  $D_2$   
28 symmetry.

1 49. A method according to claim 48, wherein  
2 none of  $Z^{10}$ ,  $Z^{10'}$ ,  $Z^{11}$ , and  $Z^{11'}$  represents a direct bond  
3 between the carbon atoms to which they are bonded.

1 50. A method according to claim 49, wherein at  
2 least one of  $Z^{10}$  and  $Z^{10'}$  has the formula  $-NQ-$ , at least  
3 one of  $Z^{11}$  and  $Z^{11'}$  is an arylene or alkylene group, and Q  
4 is an electron withdrawing group.

1 51. A method according to claim 28, wherein  
2 the compound has the formula:  
3

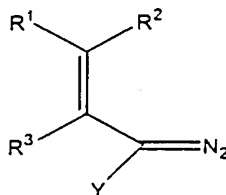
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5 wherein  $R^1$ ,  $R^2$ , and  $R^3$  are independently selected from H,  
6 alkyl, aryl, or vinyl or where  $R^1$  and  $R^3$ , together with  
7 the atoms to which they are bonded, form a 5-12 membered  
8 ring; Y is an electron withdrawing group; X is  $CH_2$ , O, or  
9  $NR^{11}$ ;  $R^{11}$  is H, an alkyl group, an aryl group, an acyl  
10 group, an alkoxy carbonyl group, or a silyl group having  
11 the formula  $-SiR^{33}R^{34}R^{35}$ ;  $R^{33}$ ,  $R^{34}$ , and  $R^{35}$  are independently  
12 selected from an alkyl group and an aryl group; and n is  
13 3-10; and wherein said method comprises:

14 providing a diazo compound having the formula:

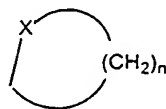
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16 and

17 converting the diazo compound with a cyclic  
18 compound having the formula:

19



20 in the presence of a bis-transition metal catalyst and  
21 under conditions effective to produce the compound,  
22 wherein  $X'$  is  $CH_2$ , O, or  $NR^{11'}$ ;  $R^{11'}$  is an alkyl group, an  
23 aryl group, an acyl group, an alkoxy carbonyl group, or a  
24 silyl group having the formula  $-SiR^{33}R^{34}R^{35}$ ; and  $R^{33}$ ,  $R^{34}$ ,

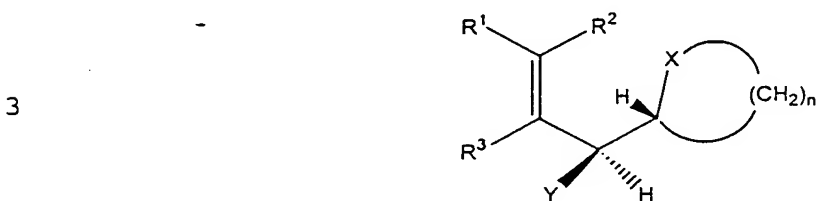
25 and  $R^{35}$  are independently selected from an alkyl group and  
26 an aryl group, provided that when X is O or  $CH_2$ , and when  
27  $R^1$  and  $R^3$ , together with the atoms to which they are  
28 bonded, form a 5-12 membered ring, said converting is  
29 carried out substantially in the absence of oxygen.

1 52. A method according to claim 51, wherein  $R^1$   
2 and  $R^3$ , together with the atoms to which they are bonded,  
3 form a phenyl ring.

1 53. A method according to claim 51, wherein Y  
2 has the formula  $-CO_2R^{10}$  and wherein  $R^{10}$  is an alkyl or aryl  
3 group.

1 54. A method according to claim 51, wherein X  
2 is  $NR^{11}$  and n is 3 or 4.

1 55. A method according to claim 51, wherein  
2 the compound has the formula:



4 and wherein the bis-transition metal catalyst is a chiral  
5 bis-transition metal catalyst.

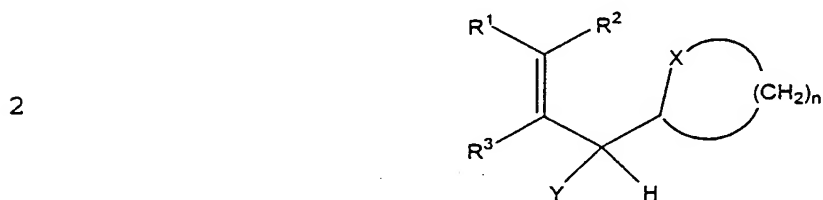
1 56. A method according to claim 55, wherein X  
2 is  $NR^{11}$ , n is 3, Y is  $CO_2R^{12}$ ,  $R^{12}$  is alkyl or aryl, and  $R^1$   
3 and  $R^3$ , together with the atoms to which they are bonded,  
4 form an aromatic ring.

1           57. A method according to claim 56, wherein X  
2 is NH, R<sup>12</sup> is a methyl group, and R<sup>1</sup> and R<sup>3</sup>, together with  
3 the atoms to which they are bonded, form a phenyl ring.

1           58. A method according to claim 51, wherein X  
2 is O or CH<sub>2</sub> and wherein said converting is carried out  
3 substantially in the absence of oxygen.

1           59. A method according to claim 58, wherein  
2 said converting is carried out in a degassed solution.

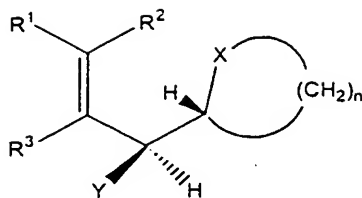
1           60. A compound having the formula:



3 wherein R<sup>1</sup>, R<sup>2</sup>, and R<sup>3</sup> are independently selected from H,  
4 alkyl, aryl, or vinyl or where R<sup>1</sup> and R<sup>3</sup>, together with  
5 the atoms to which they are bonded, form a 5-12 membered  
6 ring; Y is an electron withdrawing group; X is CH<sub>2</sub>, O, or  
7 NR<sup>11</sup>; R<sup>11</sup> is H, an alkyl group, an aryl group, an acyl  
8 group, an alkoxycarbonyl group, or a silyl group having  
9 the formula -SiR<sup>33</sup>R<sup>34</sup>R<sup>35</sup>; R<sup>33</sup>, R<sup>34</sup>, and R<sup>35</sup> are independently  
10 selected from an alkyl group and an aryl group; and n is  
11 3-10; and wherein said compound is produced with a method  
12 according to claim 49.

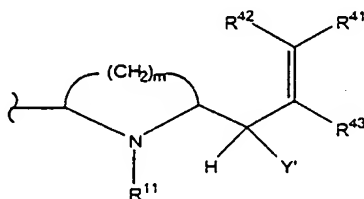
1           61. A compound having the formula:

2



3 wherein  $R^1$ ,  $R^2$ , and  $R^3$  are independently selected from H, alkyl, aryl, or vinyl or where  $R^1$  and  $R^3$ , together with the atoms to which they are bonded, form a 5-12 membered ring; Y is an electron withdrawing group; X is  $CH_2$ , O, or  $NR^{11}$ ;  $R^{11}$  is H, an alkyl group, an aryl group, an acyl group, an alkoxycarbonyl group, or a silyl group having the formula  $-SiR^{33}R^{34}R^{35}$ ;  $R^{33}$ ,  $R^{34}$ , and  $R^{35}$  are independently selected from an alkyl group and an aryl group; and n is 3-10; wherein said compound is produced with a method according to claim 55.

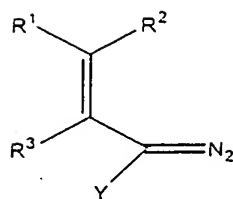
1 62. A method according to claim 28, wherein X  
2 is  $NR^{11}$  and  $R^{31}$  and  $R^{32}$ , taken together with the atoms to  
3 which they are bonded, form a ring having the formula:



4 wherein  $R^{41}$ ,  $R^{42}$ , and  $R^{43}$  are independently selected from H, alkyl, aryl, or vinyl or wherein  $R^{41}$  and  $R^{43}$ , together with the atoms to which they are bonded, form a 5-12 membered ring; Y' is an electron withdrawing group; and m is 2-9, said method comprising:  
10 providing a diazo compound having the formula:



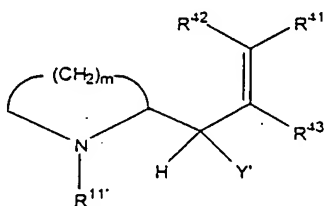
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12 and

13 converting the diazo compound with a cyclic  
14 amine having the formula:

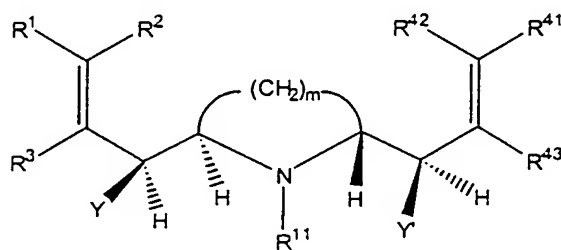
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16 in the presence of a bis-transition metal catalyst and  
17 under conditions effective to produce the compound.

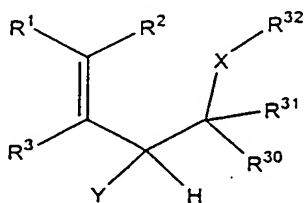
1 63. A method according to claim 62, wherein  
2 the compound has the formula:

3



1 64. A method according to claim 28, wherein  
2 the compound has the formula:

3



4 wherein R<sup>1</sup>, R<sup>2</sup>, and R<sup>3</sup> are independently selected from H,  
5 alkyl, aryl, or vinyl or where R<sup>1</sup> and R<sup>3</sup>, together with  
6 the atoms to which they are bonded, form a 5-12 membered  
7 ring; Y is an electron withdrawing group; X is CH<sub>2</sub>, O, or  
8 NR<sup>11</sup>; R<sup>11</sup> is H, an alkyl group, an aryl group, an acyl  
9 group, an alkoxycarbonyl group, or a silyl group having  
10 the formula -SiR<sup>33</sup>R<sup>34</sup>R<sup>35</sup>; each of R<sup>30</sup> and R<sup>31</sup> is  
11 independently selected from the group consisting of H,  
12 alkyl, aryl, and vinyl; R<sup>32</sup> is an alkyl group, an aryl  
13 group, an acyl group, an alkoxycarbonyl group, or a silyl  
14 group having the formula -SiR<sup>36</sup>R<sup>37</sup>R<sup>38</sup>; and R<sup>33</sup>, R<sup>34</sup>, R<sup>35</sup>, R<sup>36</sup>,  
15 R<sup>37</sup>, and R<sup>38</sup> are independently selected from an alkyl group  
16 and an aryl group; provided that when each of R<sup>30</sup> and R<sup>31</sup>  
17 is H, X is not CH<sub>2</sub>, said method comprising:

18 providing a diazo compound having the formula:



20 and

21           - converting the diazo compound with a material  
22 having the formula:



24 in the presence of a bis-transition metal catalyst and  
25 under conditions effective to produce the compound,  
26 wherein X' is CH<sub>2</sub>, O, or NR<sup>11'</sup>; R<sup>11'</sup> is an alkyl group, an  
27 aryl group, an acyl group, an alkoxycarbonyl group, or a  
28 silyl group having the formula -SiR<sup>36</sup>R<sup>37</sup>R<sup>38</sup>; and R<sup>33</sup>, R<sup>34</sup>,

29 and R<sup>35</sup> are independently selected from an alkyl group and  
30 an aryl group.

1 65. A method according to claim 64, wherein X  
2 is O, R<sup>32</sup> is a trialkylsilyl group or a triarylsilyl  
3 group, and R<sup>31</sup> is H.

1 66. A method according to claim 64, wherein X  
2 is NR<sup>11</sup>, R<sup>11</sup> is an alkyl group, and R<sup>32</sup> is selected from an  
3 acyl group and an alkoxycarbonyl group.

1 67. A method according to claim 64, wherein R<sup>1</sup>  
2 and R<sup>3</sup> are independently selected from H, alkyl, aryl, or  
3 vinyl.

1 68. A method according to claim 64, wherein R<sup>1</sup>  
2 and R<sup>3</sup>, together with the atoms to which they are bonded,  
3 form a 5-12 membered ring.

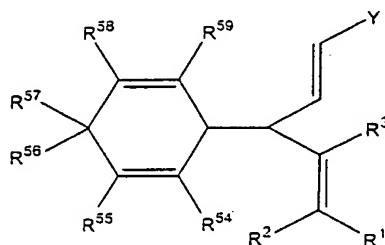
1 69. A compound having the formula:



3 wherein R<sup>1</sup>, R<sup>2</sup>, and R<sup>3</sup> are independently selected from H,  
4 alkyl, aryl, or vinyl or where R<sup>1</sup> and R<sup>3</sup>, together with  
5 the atoms to which they are bonded, form a 5-12 membered  
6 ring; Y is an electron withdrawing group; X is CH<sub>2</sub>, O, or  
7 NR<sup>11</sup>; R<sup>11</sup> is H, an alkyl group, an aryl group, an acyl  
8 group, an alkoxycarbonyl group, or a silyl group having

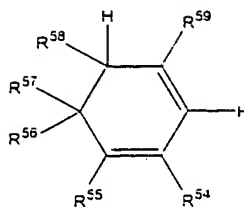
9 the formula  $-\text{SiR}^{33}\text{R}^{34}\text{R}^{35}$ ; each of  $\text{R}^{30}$  and  $\text{R}^{31}$  is  
 10 independently selected from the group consisting of H,  
 11 alkyl, aryl, and vinyl;  $\text{R}^{32}$  is an alkyl group, an aryl  
 12 group, an acyl group, an alkoxy carbonyl group, or a silyl  
 13 group having the formula  $-\text{SiR}^{36}\text{R}^{37}\text{R}^{38}$ ; or  $\text{R}^{31}$  and  $\text{R}^{32}$ ,  
 14 together with the atoms to which they are bonded, form a  
 15 5-12 membered ring;  $\text{R}^{33}$ ,  $\text{R}^{34}$ ,  $\text{R}^{35}$ ,  $\text{R}^{36}$ ,  $\text{R}^{37}$ , and  $\text{R}^{38}$  are  
 16 independently selected from an alkyl group and an aryl  
 17 group; provided that when each of  $\text{R}^{30}$  and  $\text{R}^{31}$  is H, X is  
 18 not  $\text{CH}_2$ ; and wherein said compound is produced with a  
 19 method according to claim 28.

1 70. A method for producing a compound having  
 2 the formula:



4 wherein  $\text{R}^1$ ,  $\text{R}^2$ , and  $\text{R}^3$  are independently selected from H,  
 5 an alkyl group, an aryl group, or a vinyl group or where  
 6  $\text{R}^1$  and  $\text{R}^3$ , together with the atoms to which they are  
 7 bonded, form a 5-12 membered ring; Y is an electron  
 8 withdrawing group; and  $\text{R}^{54}$ ,  $\text{R}^{55}$ ,  $\text{R}^{56}$ ,  $\text{R}^{57}$ ,  $\text{R}^{58}$ , and  $\text{R}^{59}$  are  
 9 independently selected from the group consisting of H,  
 10 alkyl, aryl, halogen, and alkoxy, said method comprising:  
 11 providing a 1,3-cyclohexadiene having the  
 12 formula:

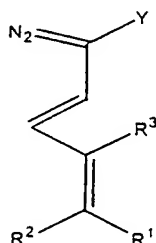
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14 and

15 converting the 1,3-cyclohexadiene with a diazo  
16 compound having the formula:

17



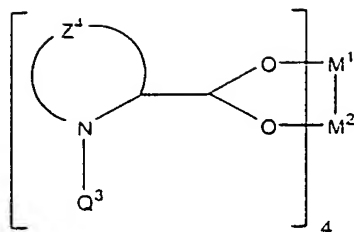
18 in the presence of a bis-transition metal catalyst and  
19 under conditions effective to produce the compound.

1 71. A method according to claim 70, wherein  
2 the bis-transition metal catalyst is a dirhodium or  
3 diruthenium catalyst.

1 72. A method according to claim 71, wherein  
2 the dirhodium or diruthenium catalyst is a dirhodium or  
3 diruthenium tetracarboxylate catalyst.

1 73. A method according to claim 72, wherein  
2 the dirhodium or diruthenium tetracarboxylate catalyst  
3 has the formula:

4



5 wherein each of M¹ and M² is Rh or Ru; Z¹ represents the  
6 atoms necessary to complete a 3-12 membered heterocyclic  
7 ring; and Q³ is an electron withdrawing group.

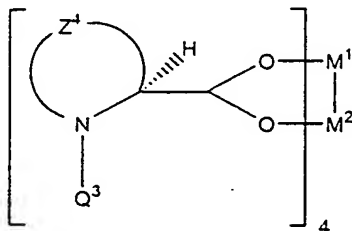
1 74. A method according to claim 73, wherein Z¹  
2 has the formula -CH₂CH₂CH₂-.

1 75. A method according to claim 73, wherein Q³  
2 is selected from the group of moieties having the  
3 formulae -C(O)R⁹, -SO₂R⁹, and -P(O)R⁹R⁹' and wherein each of  
4 R⁹ and R⁹' is independently selected from an alkyl group,  
5 an aryl group, and an alkoxy group.

1 76. A method according to claim 75, wherein Q³  
2 has the formula -SO₂R⁹ and wherein R⁹ is an alkyl or aryl  
3 group.

1 77. A method according to claim 73, wherein  
2 the dirhodium or diruthenium tetracarboxylate catalyst  
3 has the formula:

4



1  
2  
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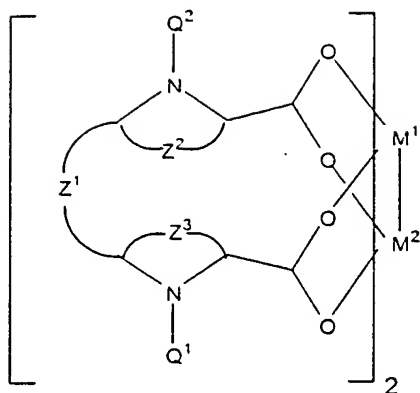
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- 2
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4



1                    81. A method according to claim 79, wherein  
2 each of M¹ and M² is Rh.

1                    82. A method according to claim 79, wherein Q¹  
2 is selected from the group of moieties having the  
3 formulae -C(O)R¹, -SO₂R¹, and -P(O)R¹R¹'; wherein Q² is  
4 selected from the group of moieties having the formulae  
5 -C(O)R², -SO₂R², and -P(O)R²R²'; and wherein each of R¹, R¹',  
6 R², and R²' is independently selected from an alkyl group,  
7 an aryl group, and an alkoxy group.

1                    - 83. A method according to claim 79, wherein Q¹  
2 has the formula -SO₂R¹; Q² has the formula -SO₂R²; and R¹  
3 and R² are the same or different and are alkyl or aryl  
4 groups.

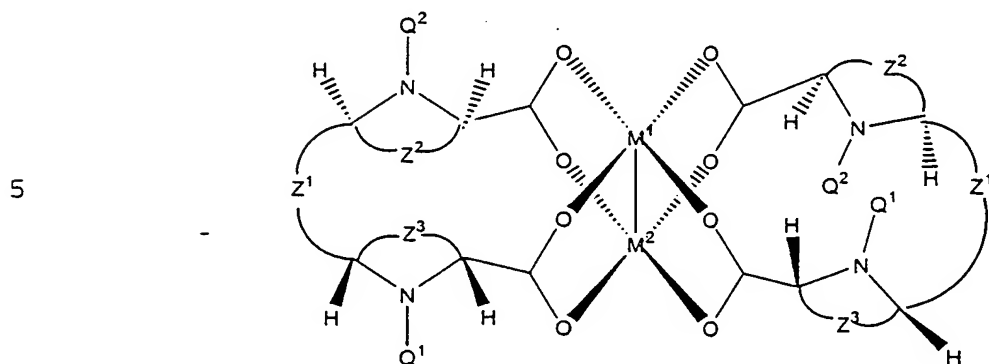
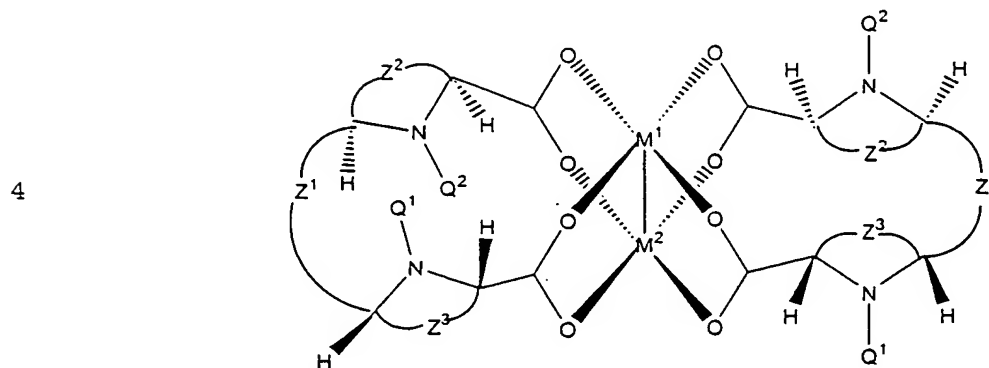
1                    84. A method according to claim 83, wherein  
2 each of R¹ and R² is independently selected from the group  
3 consisting of 4-(t-butyl)phenyl, 2,4,6-trimethylphenyl,  
4 and 2,4,6-triisopropylphenyl.

1                    85. A method according to claim 79, wherein Z²  
2 and Z³ each have the formula -CH₂CH₂-.

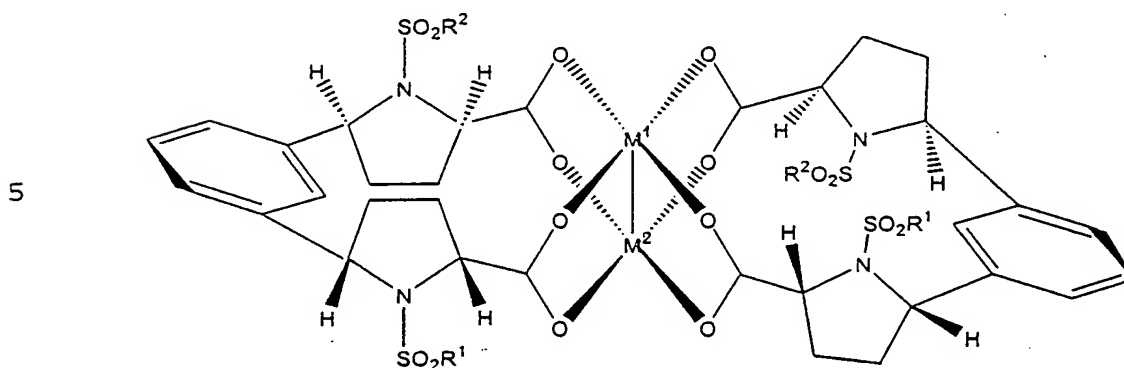
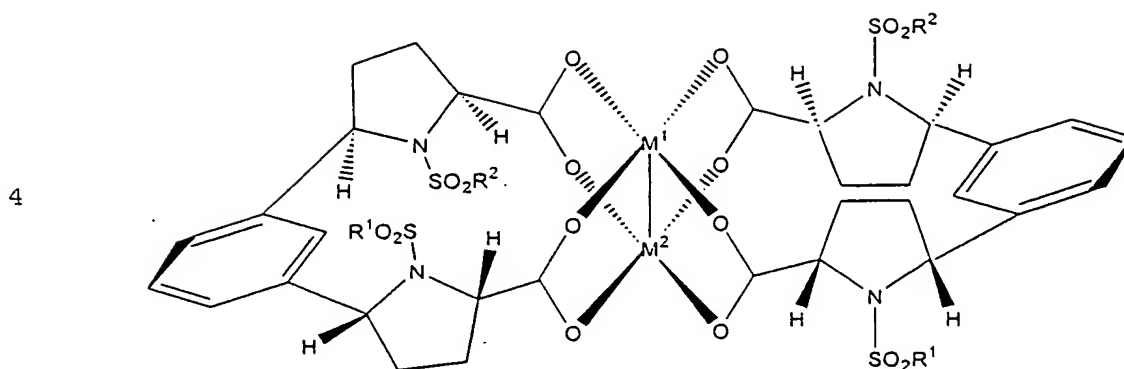


1           86. A method according to claim 79, wherein  $Z^1$   
2 is 1,3-phenylene.

1           87. A method according to claim 79, wherein  
2 the dirhodium or diruthenium tetracarboxylate catalyst  
3 has one of the following formulae:



1           88. A method according to claim 79, wherein  
2 the dirhodium or diruthenium tetracarboxylate catalyst  
3 has one of the following formulae:

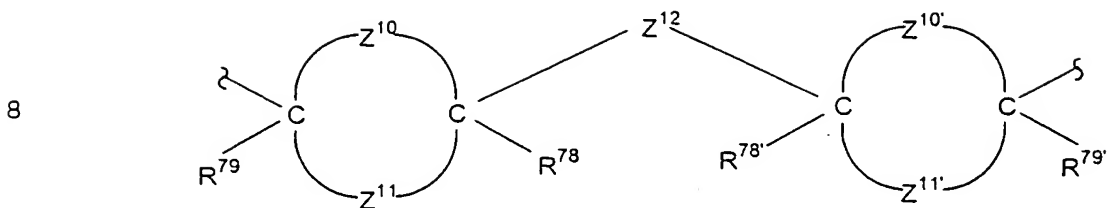


6

7 wherein  $R^1$  and  $R^2$  are the same or different and are alkyl  
8 or aryl groups.

1 89. A method according to claim 71, wherein  
2 the dirhodium or diruthenium catalyst is a chiral  
3 dirhodium or diruthenium catalyst.

1 90. A method according to claim 89, wherein  
2 the chiral dirhodium or diruthenium catalyst comprises:  
3 a first metal atom and a second metal atom  
4 bonded to one another along an axis and  
5 two carboxylate ligands wherein each of said  
6 two carboxylate ligands comprises two carboxylate groups  
7 bonded to each other via a moiety having the formula:



9 wherein Z<sup>10</sup> and Z<sup>11</sup>, together with the atoms to which they  
 10 are bonded form a 3-12 membered ring; wherein Z<sup>10'</sup> and Z<sup>11'</sup>,  
 11 together with the atoms to which they are bonded form a  
 12 3-12 membered ring; wherein R<sup>78</sup>, R<sup>78'</sup>, R<sup>79</sup>, and R<sup>79'</sup> are  
 13 independently selected from the group consisting of H, an  
 14 alkyl group, and an aryl group; wherein Z<sup>12</sup> is an alkylene  
 15 or arylene group; wherein each of said two carboxylate  
 16 groups comprises a first carboxylate oxygen atom ("O<sup>1</sup>"), a  
 17 second carboxylate oxygen atom ("O<sup>2</sup>"), and a carbon ("C")  
 18 to which said O<sup>1</sup> and said O<sup>2</sup> are bonded thereby forming  
 19 two O<sup>1</sup>-C-O<sup>2</sup> moieties, each O<sup>1</sup>-C-O<sup>2</sup> moiety defining a plane  
 20 which is substantially parallel to said axis; wherein  
 21 said O<sup>1</sup> of each of said two carboxylate groups of each of  
 22 said two carboxylate ligands is bonded to said first  
 23 metal atom; wherein said O<sup>2</sup> of each of said two  
 24 carboxylate groups of each of said two carboxylate  
 25 ligands is bonded to said second metal atom; wherein each  
 26 of said two carboxylate ligands further comprises at  
 27 least two chiral centers; and wherein said compound has D<sub>2</sub>  
 28 symmetry.

1 91. A method according to claim 90, wherein  
 2 none of Z<sup>10</sup>, Z<sup>10'</sup>, Z<sup>11</sup>, and Z<sup>11'</sup> represents a direct bond  
 3 between the carbon atoms to which they are bonded.

1 92. A method according to claim 91, wherein at  
 2 least one of Z<sup>10</sup> and Z<sup>10'</sup> has the formula -NQ-, at least

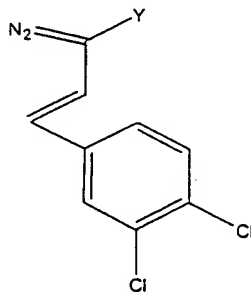
3 one of  $Z^{11}$  and  $Z^{11'}$  is an arylene or alkylene group, and Q  
4 is an electron withdrawing group.

1 93. A method according to claim 70, wherein Y  
2 is an alkoxy carbonyl group.

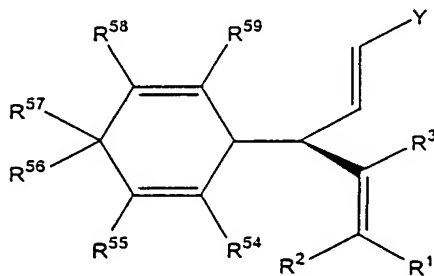
1 94. A method according to claim 93, wherein Y  
2 has the formula  $-\text{COOR}^{12}$  and  $R^{12}$  is an alkyl group.

1 95. A method according to claim 70, wherein  $R^1$   
2 and  $R^3$ , together with the atoms to which they are bonded,  
3 form an aromatic ring.

1 96. A method according to claim 95, wherein  
2 the diazo compound has the formula:



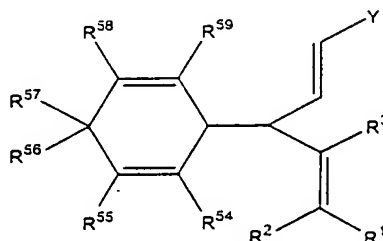
1 97. A method according to claim 70, wherein  
2 the compound has the formula:



4 and wherein the bis-transition metal catalyst is a chiral  
5 bis-transition metal catalyst.

1                    98. A method according to claim 97, wherein  
2 the chiral bis-transition metal catalyst is a chiral  
3 dirhodium or diruthenium catalyst.

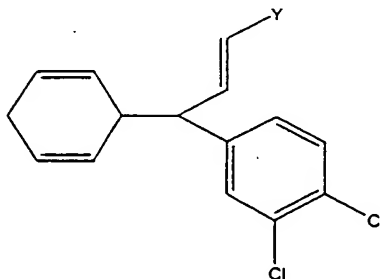
1                    99. A compound having the formula:



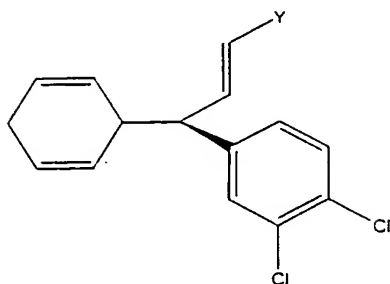
3 wherein R<sup>1</sup>, R<sup>2</sup>, and R<sup>3</sup> are independently selected from H,  
4 an alkyl group, an aryl group, or a vinyl group or where  
5 R<sup>1</sup> and R<sup>3</sup>, together with the atoms to which they are  
6 bonded, form a 5-12 membered ring; Y is an electron  
7 withdrawing group; and R<sup>54</sup>, R<sup>55</sup>, R<sup>56</sup>, R<sup>57</sup>, R<sup>58</sup>, and R<sup>59</sup> are  
8 independently selected from the group consisting of H,  
9 alkyl, aryl, halogen, and alkoxy.

1                    100. A compound according to claim 99, wherein  
2 R<sup>1</sup> and R<sup>3</sup>, together with the atoms to which they are  
3 bonded, form a substituted or unsubstituted 1,3-phenylene  
4 ring.

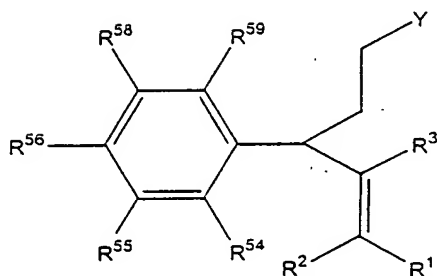
1                    101. A compound according to claim 100,  
2 wherein said compound has the formula:



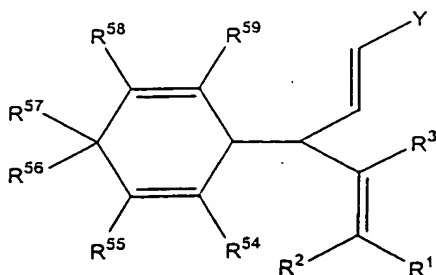
1                    102. A compound according to claim 99, wherein  
2       said compound has the formula:



1                    103. A method for making a compound having the  
2       formula:



4       wherein R<sup>1</sup>, R<sup>2</sup>, and R<sup>3</sup> are independently selected from H,  
5       an alkyl group, an aryl group, or a vinyl group or where  
6       R<sup>1</sup> and R<sup>3</sup>, together with the atoms to which they are  
7       bonded, form a 5-12 membered ring; Y is an electron  
8       withdrawing group; and R<sup>54</sup>, R<sup>55</sup>, R<sup>56</sup>, R<sup>58</sup>, and R<sup>59</sup> are  
9       independently selected from the group consisting of H,  
10      alkyl, aryl, halogen, and alkoxy, said method comprising:  
11                    providing a cyclohexadiene derivative having  
12      the formula:



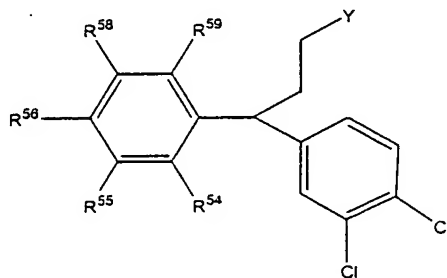
14 wherein  $R^{57}$  is H, and  
15 converting the cyclohexadiene derivative with  
16 hydrogenating and oxidizing agents under conditions  
17 effective to form the compound.

1 104. A method according to claim 103, wherein  
2 Y is an alkoxycarbonyl group.

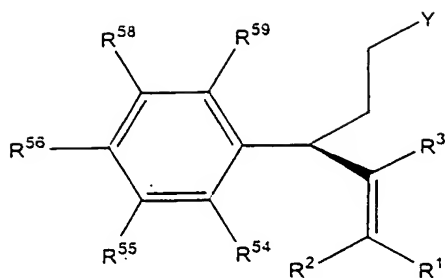
1 105. A method according to claim 104, wherein  
2 Y has the formula  $-\text{COOR}^{12}$  and  $R^{12}$  is an alkyl group.

1 106. A method according to claim 103, wherein  
2  $R^1$  and  $R^3$ , together with the atoms to which they are  
3 bonded, form an aromatic ring.

1 107. A method according to claim 106, wherein  
2 the compound has the formula:



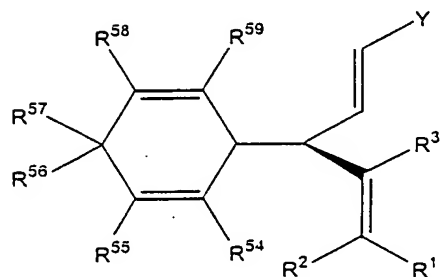
1 108. A method according to claim 103, wherein  
2 the compound has the formula:



3

4

5 and wherein the cyclohexadiene derivative has the  
6 formula:



7

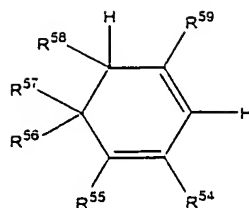
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1 109. A method according to claim 108, wherein  
2 R<sup>1</sup> and R<sup>3</sup>, together with the atoms to which they are  
3 bonded, form an aromatic ring.

1 110. A method according to claim 109, wherein  
2 R<sup>1</sup> and R<sup>3</sup>, together with the atoms to which they are  
3 bonded, form a substituted or unsubstituted 1,3-phenylene  
4 ring.

1 111. A method according to claim 103, wherein  
2 said providing a cyclohexadiene derivative comprises:  
3 providing a 1,3-cyclohexadiene having the  
4 formula:

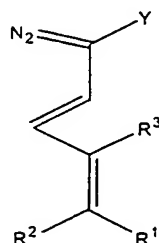




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6 and

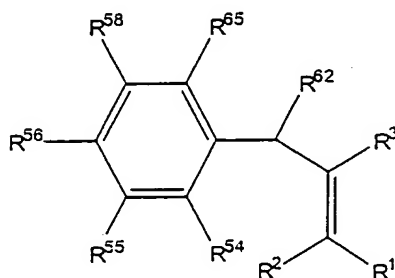
7 converting the 1,3-cyclohexadiene with a diazo  
8 compound having the formula:



9

10 in the presence of a bis-transition metal catalyst and  
11 under conditions effective to produce the cyclohexadiene  
12 derivative.

1 112. A method for preparing a compound having  
2 the formula:

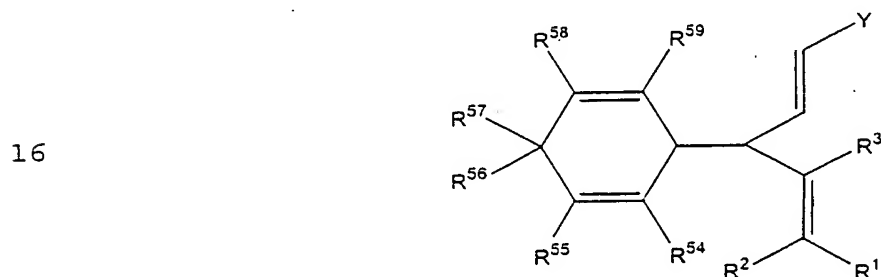


3

4 wherein R<sup>1</sup>, R<sup>2</sup>, and R<sup>3</sup> are independently selected from H,  
5 an alkyl group, an aryl group, or a vinyl group or where  
6 R<sup>1</sup> and R<sup>3</sup>, together with the atoms to which they are  
7 bonded, form a 5-12 membered ring; R<sup>54</sup>, R<sup>55</sup>, R<sup>56</sup>, R<sup>58</sup>, and

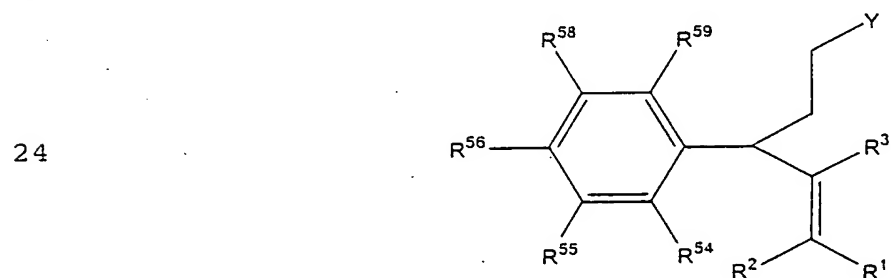
8  $R^{55}$  are independently selected from the group consisting  
 9 of H, alkyl groups, aryl groups, halogen, amino groups,  
 10 alkoxy groups, hydroxy groups, and acid groups;  $R^{52}$   
 11 represents an alkyl moiety; or  $R^{55}$  and  $R^{52}$  together  
 12 represent the atoms necessary to complete a 5-12 membered  
 13 ring, said method comprising:

14 providing a cyclohexadiene derivative having  
 15 the formula:



17 wherein  $R^{57}$  is H,  $R^{59}$  is selected from the group consisting  
 18 of H, alkyl groups, aryl groups, halogen, amino groups,  
 19 alkoxy groups, hydroxy groups, and acid groups, and  $Y$  is  
 20 an electron withdrawing group,

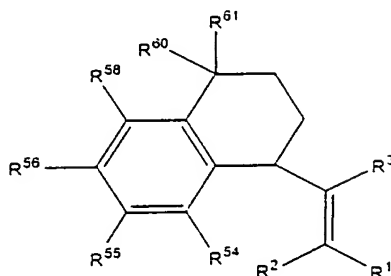
21 converting the cyclohexadiene derivative with  
 22 hydrogenating and oxidizing agents under conditions  
 23 effective to form a phenyl derivative having the formula:



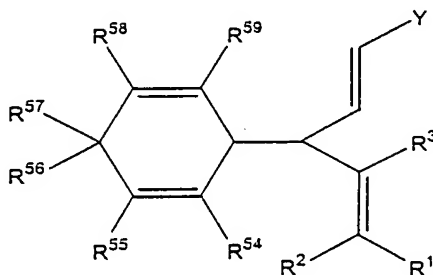
25 and

26 converting the phenyl derivative under  
 27 conditions effective to produce the compound.

1 113. A method according to claim 112, wherein  
2 the compound has the formula:



4 and wherein  $R^{60}$  is H and  $R^{61}$  represents a substituted or  
5 unsubstituted amine or  $R^{60}$  and  $R^{61}$ , together with the  
6 carbon atom to which they are bonded, represent a  
7 carbonyl moiety, said method comprising:  
8 providing a cyclohexadiene derivative having  
9 the formula:



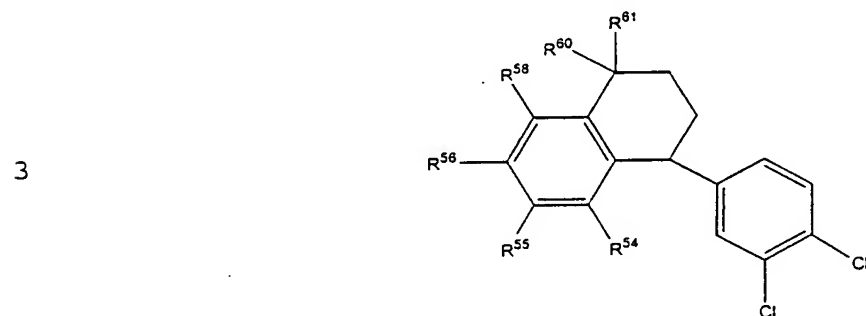
11 wherein Y is an electron withdrawing group and  $R^{57}$  and  $R^{59}$   
12 are H, and  
13 converting the cyclohexadiene derivative with a  
14 hydrogenating agent, an oxidizing agent, and a cyclizing  
15 agent under conditions effective to form the compound.

1 114. A method according to claim 113, wherein  
2 the cyclizing agent is a Friedel Crafts acylation  
3 catalyst.

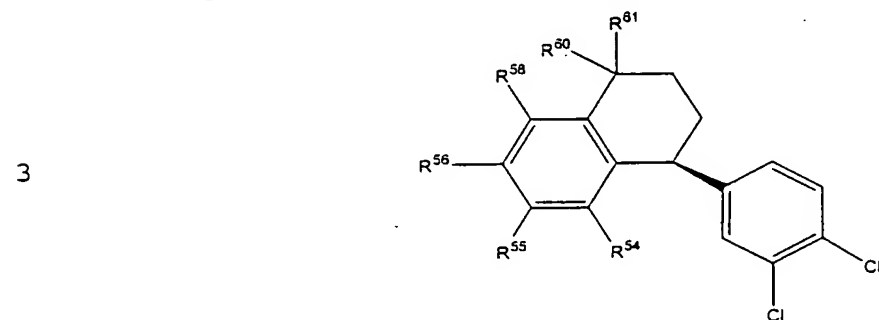
1           115. A method according to claim 113, wherein  
2  $R^{60}$  has the formula  $-NR^{63}R^{64}$ , wherein each of  $R^{63}$  and  $R^{64}$  is  
3 independently selected from H, an alkyl group, and an  
4 aryl group.

1           116. A method according to claim 113, wherein  
2  $R^1$  and  $R^3$ , together with the atoms to which they are  
3 bonded, form an aromatic ring.

1           117. A method according to claim 116, wherein  
2 the compound has the formula:

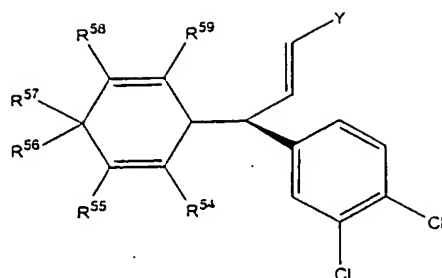


1           118. A method according to claim 113, wherein  
2 the compound has the formula:



4 and wherein the cyclohexadiene derivative has the  
5 formula:

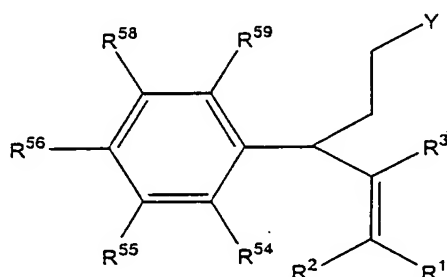
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1           119. A method according to claim 113, wherein  
2 said converting the cyclohexadiene derivative with a  
3 hydrogenating agent, an oxidizing agent, and a cyclizing  
4 agent under conditions effective to form the compound  
5 comprises:

6           converting the cyclohexadiene derivative with a  
7 hydrogenating agent and an oxidizing agent into a phenyl  
8 derivative having the formula:

9



10 and

11           converting the phenyl derivative with a  
12 cyclizing agent under conditions effective to produce the  
13 compound.

1           120. A method according to claim 119, wherein  
2 the cyclizing agent is a Friedel Crafts acylation  
3 catalyst.

1                   121. A method according to claim 112, wherein  
2   R<sup>1</sup> and R<sup>3</sup>, together with the atoms to which they are  
3   bonded, form an aromatic ring.

1                   122. A method according to claim 121, wherein  
2   R<sup>1</sup> and R<sup>3</sup>, together with the atoms to which they are  
3   bonded, form a substituted or unsubstituted 1,3-phenylene  
4   ring.

1                   123. A method according to claim 112, wherein  
2   Y is an alkoxycarbonyl group.

1                   124. A method according to claim 123, wherein  
2   Y has the formula -COOR<sup>12</sup> and R<sup>12</sup> is an alkyl group.